This brochure is directed to those who manage dams permitted by the State of Iowa. The State has authority to continue oversight of those dams through inspections to enforce compliance with safe operation and maintenance standards.

This is not a complete maintenance manual. Its intent is to alert owners to items that need frequent attention and to increase awareness of responsibilities among Iowa dam owners and operators, and those who maintain dams.

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Maintenance Manual
for
Dam Owners

Dams need to be used efficiently and managed to protect environmental quality, enhance public safety and flood protection, and to support and balance a variety of economic, social and ecological needs.

Iowa Department of Natural Resources 2004

Importance of Dam Safety

While **dams** are not part of the natural landscape, the man-made structures must be designed, inspected, operated and maintained properly to protect their natural surroundings.

Routine maintenance and inspection of dams and related facilities must be an ongoing process to prevent **dam failures**. Negligence can threaten overall safety of a dam and have a catastrophic impact on communities, private property and public works downstream. Dam failures causing extensive damage or loss of life are not frequent, but failures do occur and are a legitimate public concern.

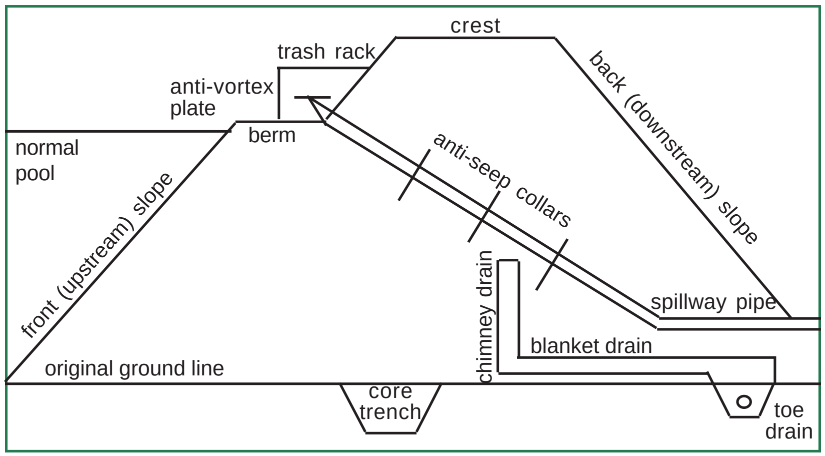

Figure 1: Cross section of a typical Iowa embankment dam

Liability and Responsibility

Owning a dam carries significant legal responsibilities, and owners should be aware of potential liabilities.

A dam owner is responsible for its safety, and liability can be imposed upon a dam owner if he or she fails to maintain, repair or operate the dam in a safe and proper manner. This liability also applies to any person who operates or maintains the dam. The extent of liability may depend upon the degree of care employed by the owner in constructing, operating and maintaining a dam.

**Boldface items are defined in the glossary at the end of this booklet.

If an unsafe condition existed prior to ownership of the dam, the new owner may not be cleared of liability should the dam fail during his or her term of ownership. A prospective owner should carefully inspect the integrity of a dam prior to purchase. The Iowa Department of Natural Resources (DNR) can provide information on recent inspections of the dam.

Dam Embankment

Vegetation

Vegetation, depending upon its type and location, may be beneficial or detrimental to the integrity of dams and spillways.

Trees and Brush

Trees and brush are not permitted on **embankments** or in vegetated earth spillways, as root systems provide **seepage** paths for water, especially after roots decay. Trees that fall over or are blown down can leave large holes in the embankment surface, weakening the embankment and possibly leading to increased erosion or even immediate failure.

Tree and brush growth hinders inspection of the embankment and slows growth of protective grasses.

Woody growth obscures the surface of the dam, limits visual inspection, provides a haven for burrowing animals and slows growth of protective grass vegetation.

Tree and brush growth can damage concrete walls and structures through physical force against the structure, through potential seepage paths created by roots, and by clogging drainage pipes and **weep holes**.

If large trees have been allowed on embankments, the entire root system should be removed and the cavity refilled with well-compacted, non-porous soil. Small trees must be cut at ground level so that mowing may be done efficiently.

A good vegetative cover on the embankment and along the shore line helps prevent erosion.

Stumps in **riprap** usually cannot be pulled or ground down, but can be chemically treated so as to avoid formation of new sprouts.

Grass Vegetation

Grass vegetation is generally an effective and inexpensive way to slow erosion of shoreline, embankment and earth spillway surfaces. If properly maintained, it also enhances the appearance of the lake and dam. Grass cover provides a surface that can be easily inspected. Roots and stems tend to trap soil particles, forming an erosion-resistant layer once plants are well established.

Throughout Iowa, common brome is a preferred grass, as it is sod-forming, perennially durable and relatively easy to establish. At some dams, bluegrass may be preferred. Clump-forming vegetation such as fescue and alfalfa are to be avoided, and crown vetch is not recommended.

Grass cover should be maintained at several inches in height, and bare areas and eroded locations should be promptly repaired. Maintenance should include the prevention of excessive weed growth and woody infestation.

Grazing can result in a thin grass cover.

Uncontrolled livestock grazing on embankments and in **emergency spillways** frequently results in diminished vegetative quality, causing ground surfaces to be less resistant to erosion. Livestock create paths and bare surfaces, which are subject to erosion.

In areas of concentrated runoff, such as the contact between embankment and **abutments** (**groins**), or areas along the waterline on the **front slope** subject to strong wave action, grass vegetation may not be adequate to control soil erosion. More rigorous protection with paved concrete or riprap may be necessary.

Slope Protection

Excessive erosion on an upstream slope, due to grazing cattle and wave action.

Special protection is usually needed to protect upstream embankment slope surfaces against erosion from wave action. Without slope protection, serious erosion known as "**beaching**" can develop on the upstream slope. Beaching is a process in which embankment soil is eroded from near- and above-normal waterline

Riprap blankets protect embankments from wave erosion.

and deposited below the waterline, forming a beach or **berm**. The deposition is not harmful, but the eroded cavity above the water line steepens a front slope and weakens the upper embankment. Carried to an ultimate result, the embankment would be destroyed.

Two general designs provide satisfactory protection from beaching. First, placement of a filter bed or suitable geotextile with proper size riprap on top provides armor-like protection. Another design for protection is a vegetated berm sloped so that part is below normal pool and part above the pool. Suitable vegetation on the berm dissipates wave energy. A third, less used, wave action erosion preventive is reinforced concrete paving. These methods require engineering design to be most effective.

Downstream embankment slopes also require surface protection against erosion, such as high-quality grass vegetation. Placing berms is also a practical method for reducing erosion damage to the **back slope**. Berms should be spaced at approximately 25-foot vertical intervals to intercept surface flow and safely carry this water to surface or subsurface outlets.

A berm on the downstream side of an embankment helps control erosion damage to the back slope.

When rill erosion or gullies form on embankment slopes, repairs should be done immediately. Eroded areas should be backfilled with well-compacted soils (the upper four inches friable topsoil) and revegetated. In instances where deep gullies have formed, straw bales or erosion control fencing may be needed until a permanent fix can be established. The cause of the gully formation, such as a concentrated flow in a groin or as the result of a low area on the **crest** or slope, should determined and taken into account when repairing the area.

Burrowing Animals

Rodents and other burrowing animals are attracted to dams and **reservoirs** and can threaten the structural integrity of the embankment and spillways. Groundhog (woodchuck) and muskrat burrows weaken the embankment and can serve as pathways for seepage, which can destroy the dam, while beavers may plug the spillway and raise the pool level. Animal control is essential in preserving a well-maintained dam.

Beavers

Beavers, the largest rodents in North America, are almost entirely aquatic animals. Beavers live in family groups inside burrows that are built in stream banks, or they live in lodges made of mud, stones and tree branches. To protect themselves from predators, beavers use subsurface entrances and exits to the burrow. To assure adequate water depth, beavers dam streams using branches, logs, mud and stones. This construction is most harmful to dams when placed in front of spillway inlets, raising the normal water level and adversly affecting spillway performance.

Unlike groundhogs and muskrats, beavers seldom burrow into a dam. Beavers may leave a site when their dam is repeatedly damaged. Hunting, trapping and poisoning are alternative means for controlling the beaver population, provided all applicable local and state laws are followed.

Groundhogs / Woodchucks

Occupied groundhog burrows are easily recognized in the spring due to the groundhog's habit of house cleaning. Fresh dirt is generally found at the mouth of active burrows. Half-round mounds, paths leading from the den, and clawed or girdled trees and shrubs help identify burrows.

When burrowing into an embankment, groundhogs stay above the **phreatic surface** (upper surface of seepage or saturation) to stay dry. The burrow is seldom a single tunnel. It is usually forked, with more than one entrance and several side passages, or rooms, up to 12 feet long.

Locating a rodent burrow near an emergency spillway.

Control methods may best be implemented during early spring when active burrows are easy to find, young groundhogs have not scattered and there is less likelihood of damage to other wildlife. Groundhogs can be controlled by using fumigants, the most practical control method, or by shooting. Keeping vegetative cover mowed will discourage groundhogs from inhabiting the embankment.

Muskrats

Muskrats may be found wherever there are marshes, swamps, ponds, lakes and streams with calm or very slowly moving water and vegetation in the water and along banks. Muskrats make their homes by burrowing into the banks of lakes and streams, or by building houses of bushes and other plants. Their burrows begin from six to 18 inches below water surface and penetrate the embankment on an upward slant. At distances up to 15 feet from the entrance, a dry chamber is hollowed out above the water level. Once a muskrat den is occupied, a rise in water level will cause the muskrat to dig farther and higher to form a new dry chamber.

As shown in Figure 2 below, damage is compounded where groundhogs, or other burrowing animals, construct their dens in the embankment opposite muskrat dens.

Barriers to prevent burrowing offer the most practical protection to structures. A substantial riprap and filter layer will discourage burrowing. Filter and riprap should extend at least three feet below the water line. As a muskrat attempts to construct a burrow, the sand and gravel of the filter caves in and discourages den building. Heavy, close mesh wire fencing laid flat on the slope and extending well below and above the water line can also be effective. Eliminating aquatic vegetation along the shoreline will discourage muskrat habitation, and trapping may be a practical method for removing muskrats.

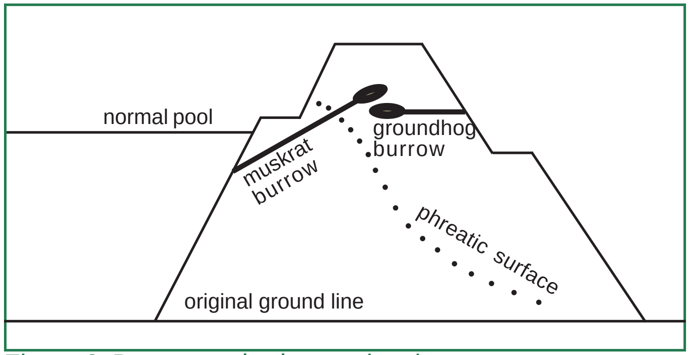

Figure 2: Dangerously close rodent burrows cause a hazard to earth dams.

All state hunting and trapping regulations *must* be followed in control of animals. If special conditions exist, it may be possible to develop a special plan for animal control in cooperation with a local DNR wildlife biologist.

Eliminating a Burrow

The recommended method for filling or plugging a burrow in an embankment is mud-packing. Place one or two lengths of stove or vent pipe in a vertical position into the entrance of the den. Make sure the pipe connection to the den does not leak. Pour the mud-pack mixture into the pipe until the burrow is filled with the earth-water mixture. Remove the pipe and pack dry earth into the entrance. Mud-pack is made by adding water to a 90 percent earth and 10 percent cement mixture until a slurry (mixture with a thin consistency) is attained. All entrances should be plugged and vegetation reestablished as soon as possible, as only one hole can lead to failure of a dam.

Embankment and Foundation Drainage

Many dams are equipped with embankment and foundation drainage systems. The drain works to intercept seepage water and to safely carry it to an outlet, so embankment soil particles do not move beyond the filter. Sand and gravel filter zones in earth dams can be configured as **chimney drains**, **blanket drains**, foundation **trench drains** and **toe drains**, for example.

Drain outlets should be regularly checked to ensure that they are unobstructed and free-flowing. Outflow from drainage systems should be clear. Muddy or cloudy discharges are an indication of problems and should be promptly investigated by a qualified individual.

When drain outlets are inspected, the quantity of flow from the outlets should be measured and recorded. The impoundment level should also be recorded. A significant change in flow, either an increase or decrease, could be an indication of a problem that requires additional investigation. Many times, the flow rate from a drain outlet can be determined by measuring the amount of time it takes to capture a gallon (or other known quantity) of water in a bucket or other container. If a clear container is used, the water clarity can be checked to see if the drain water is carrying sediment. The captured water should be kept for a short time to see if any sediment settles out of the water.

Seepage

All earth dams have seepage resulting from water percolating slowly through the dam and its foundation. Excessive seepage not picked up by an embankment or foundation drain will be noticed as wetness, springs or **boils** on the lower back slope and **toe of the dam**. A change in vegetation is another indicator of seepage. Areas with water-loving plants such as cattails, reeds and mosses or with normal vegetation that is greener and more lush than adjacent vegetation should be checked for seepage.

Seepage must be controlled in both velocity and quantity. If uncontrolled, it can progressively erode soil from the embankment or its foundation. This is known as **piping**, or internal erosion, that can result in failure of the dam.

Uncontrolled seepage, especially if it "daylights" on the downstream slope or toe of an embankment, will weaken an earth dam which can result in earth slides that may lead to structure failure.

Piping failure of a dam as a result of seepage along the spillway conduit. A hole has eroded completely through the dam.

If seepage that discharges at the downstream side of the dam carries particles of soil, an elongated cavity or "pipe" may be eroded backward through the embankment, foundation or abutment up to the reservoir. When an eroding pipe reaches the reservoir, a catastrophic **breaching** of the dam will most likely occur.

Internal erosion may take place in episodes of erosion and discharge of muddy water interspersed with periods of clear water discharge, or no discharge at all. The formation of **sinkholes** in an embankment is often an indication of the development of a piping problem. A sinkhole and vortex that develops in the impoundment is a sign that the internal erosion has progressed through the dam and complete failure is imminent.

Seepage problems are best prevented through proper design and construction. Several methods are successfully used alone or in a combination to intercept seepage as mentioned above. While steps to prevent seepage problems in the design process is advised, some well-designed dams may still develop a seepage problem. Seepage control can be added to most embankments.

Spillways

Principal Spillways

Principal spillways are used to safely carry most outflow from the reservoir. As these **spillways** have frequent or continuous discharge, concrete or metal is generally used to resist erosion of the structure. Many principal spillways consist of a closed **conduit** of round pipe or box cross-section, while other designs use an open concrete chute. A **chute spillway** may be the only spillway provided, but closed conduits generally require an emergency spillway to carry especially large inflows to the reservoir past the dam.

Closed conduits of concrete pressure pipe are frequently used as a principal spillway. These systems carry normal stream and moderate flood flows safely past the embankment. A strong emphasis on high quality design,

A typical concrete pipe hood inlet spillway with anti-vortex plate, trash rack and scour pad.

materials and construction is important, as repair is difficult due to location within the embankment. Concrete structures should be visually examined for deterioration due to weathering,

Excessive vegetation in and along a chute spillway.

unusual stresses, chemical attack, erosion, **cavitation**, vandalism and other destructive forces. Structural problems are indicated by cracking, exposure of reinforcing steel, large areas of broken-out concrete, mis-alignment at joints, undermining and settlement. Rust stains may indicate internal corrosion and deterioration of reinforcing steel. Floor slabs should be checked for erosion of underlying base material, and the vertical condition and alignment of walls should be recorded.

Deep, wide cracking is likely due to stresses which are primarily caused by shrinkage and structural loads. Minor or hairline cracking is caused by weathering or the quality of concrete. Generally, minor surface cracking does not affect structural integrity.

Cracks through concrete surfaces exposed to flowing water may lead to erosion, or piping, of soil particles from around and/or under the concrete structure. Seepage at the discharge end of a spillway may indicate **leakage** of water through a crack. Tapping the concrete surface with a hammer will help locate voids, if present, and give an indication of the concrete's condition.

Proper filter bed underdrainage for open channel spillways with concrete floors is necessary. Flows from underdrain outlets and pressure relief holes should be continually observed and measured. Cloudy flow may indicate piping is occurring beneath or adjacent to the concrete structure. Weep holes must be kept open.

Examples of metal conduit material include: ductile iron, smooth steel, and corrugated metal pipe (CMP). Corrosion is a common problem that eventually results in the breakdown of the structure. For this reason, CMP is least desirable for structures needed to have a long life.

Corrosion can be controlled by installing cathodic protection. A metal anode, such as magnesium, is buried and connected to the metal conduit by wire. Current from the magnesium (anode) to the conduit (cathode) will cause the magnesium to corrode and not the conduit. Regular inspection is necessary.

Metal spillways are also subject to the same leakage and seepage problems discussed above for concrete.

A common problem noted with spillway conduit systems is undermining. This condition typically results from water leaking through pipe joints, seepage from the reservoir following the conduit or inadequate energy dissipation at the outlet. Frequent observation of the spillway will focus attention upon change, which may predict serious trouble.

Concrete deterioration has exposed reinforcing steel and created a hole in the chute spillway floor above.

The area around the spillway outlet, particularly underneath the conduit, should be checked for cavities or voids extending upstream into the embankment. This area should also be checked for seepage. Attention should also be given to the ground surface above the spillway conduit, especially for sinkholes that could be a sign of piping or internal erosion along the conduit.

Erosion of an outlet channel.

Spillway conduits are typically provided with **trash racks**. Trash racks should be designed with openings that are small enough to keep debris from plugging the conduit but large enough for unrestricted passage of water and smaller debris. Accumulated debris should be routinely removed from the trash rack and properly disposed. Occasionally, dam owners will place hardware cloth, chicken wire or other small mesh screening around a trash rack or directly around the spillway inlet to prevent fish loss through the spillway conduit. This small mesh screen is too restrictive and prone to plugging, and should not be used. Fisheries biologists have found that fish loss through a spillway conduit is generally not a concern.

Anti-vortex devices should be installed on virtually all conduit spillways. An anti-vortex plate prohibits or slows the formation of a vortex, or swirl, at the spillway inlet. The vortex formation allows air to enter the conduit during high flow, which reduces the capacity of the spillway. On a typical hood inlet spillway, the anti-vortex device is a horizontal plate situated above the inlet. On an open drop inlet spillway, the anti-vortex device usually consists of a vertical plate or wall centered over the inlet or across the back wall of the drop inlet.

Outlet Channel

Outlet channels from principal spillways must be maintained to provide free flow from the spillway. This may include periodic excavation, and removal of trees and brush. In case of an eroding exit channel, it may be necessary to rebuild the principal spillway outlet. Excessive erosion can sometimes be controlled with riprap.

A stable and well-maintained spillway outlet and toe drain outlet.

Emergency Spillways

Emergency spillways operate only during a need for large discharges from the dam. In Iowa, most emergency spillway designs use a trapezoidal cross-section with a vegetated surface. Maintenance primarily involves repairing soil erosion, prompt removal of trees and brush, and maintaining thrifty vegetation of the nature recommended for embankments.

An emergency spillway must not be cropped or used for storage of equipment, vehicles or other items. Fences running perpendicular or otherwise across the flow path should not be built through an emergency spillway.

Permit Requirements

The DNR can provide, upon request, information about permitting requirements for new dams and for modification of existing dams.

Dam owners should be aware that a **flood plain** construction permit is required for construction of a house or other building around the impoundment, below the top of dam elevation. A flood plain permit is also needed for construction downstream of the dam in an area that would be affected by failure of the dam. Dam owners should keep these requirements in mind when planning any house or building construction.

Construction of houses or other buildings downstream of a dam may impact the dam's downstream **hazard classification**. Dams are assigned a hazard classification based on the potential for loss of life and economic impacts should the dam fail. Included are the potential damages to downstream lands, roads, houses and other development. In general, dams with higher hazard classifications must meet more stringent design standards. Should development occur downstream of the dam in areas that would be affected by the failure of the dam, the hazard classification could change and substantial modifications to upgrade the dam may be required. The dam owner should be aware of this when considering any development on lands under his or her ownership or control.

Conclusions

The DNR intends to be a helpful partner in ensuring dam safety in Iowa. Ultimately, owners are responsible for constructing and maintaining safe dams. Owners must not become complacent during periods without dam failures. There will most likely be future runoff events that will test the safety of many dams.

While an experienced dam engineer may be able to detect subtle signs of potential problems during routine inspections, the owner and on-site personnel should be aware of changes between inspections. Recording observations during monthly walkovers is suggested.

A well-vegetated and maintained emergency spillway.

The DNR wants Iowa dam owners to be as prepared as possible. Please contact the DNR for assistance or guidance or if a dam safety emergency arises. Contact information is available on the back cover of this brochure.

Glossary of Terms

These definitions apply to words used in this document and in inspection reports.

Abutment – A valley side to which the end of a dam is joined. Usually considered to include the valley sides immediately upstream and downstream from the dam.

Appurtenant structure or facility – An auxiliary feature of a dam needed for operation of the project. Examples are water intakes for pumps and features to regulate lake water surface elevation.

Auxiliary spillway (also emergency spillway) – A spillway which works in conjunction with the principal spillway, but less often. Constructed of non-erodible materials.

Back slope – The downstream slope of an embankment. The side of a dam opposite the reservoir.

Baffle block – A concrete block constructed in a concrete chute, channel or stilling basin to dissipate energy of rapidly flowing water.

Beaching – Erosion of soil material on the upstream side of the embankment and deposition of that material down slope so as to create a beach-like area.

Berm – A horizontal step or bench in the slope of an embankment.

Blanket Drain – A generally horizontal granular drain (like a blanket) that extends under a relatively large area of the downstream embankment.

Boil – Uncontrolled seepage from a dam that is under pressure and appears to bubble as it reaches the surface. It may be accompanied by deposition of a ring of soil or sand (volcano like) around where the water escapes.

Breach – A rapidly forming opening that allows impounded water to pass through a dam virtually uncontrolled.

Cavitation – Damage caused to hydraulic structures from pressure changes in the water. Typically caused by abrupt changes in direction and velocity of the water.

Chimney drain – A vertical or inclined zone of pervious material in an embankment dam that intercepts seepage water and safely discharges it downstream of the dam.

Chute spillway – An open spillway usually constructed of concrete.

Conduit – A pipe or box structure of metal or concrete made to carry water from the reservoir. Usually part of a principal spillway.

Core – A zone of compacted, low permeability material in an embankment dam.

A beaver dam surrounds a drop inlet road grade structure. Keeping beavers and burrowing animals under control is important for maintaining a dam.

Crest – The top surface of a dam. Also the high point, or controlling elevation, of a spillway.

Cutoff wall – A wall of impervious material, like concrete, soil-bentonite, cement-bentonite, asphaltic concrete, or steel sheet piling constructed under or through a dam to halt seepage.

Dam – A barrier constructed across a watercourse for the purpose of storage, control or diversion of water.

Dam failure – The breakdown of a dam characterized by uncontrolled release of impounded water. There are varying degrees of failure.

Dam safety – The art and science of ensuring integrity and viability of dams such that they are not an unacceptable risk to people, property or the environment.

Downstream channel – Waterway downstream from a dam in which water is returned to the original stream.

Embankment – Fill material, usually earth or rock, placed with sloping sides.

Emergency spillway (also auxiliary spillway) – A secondary spillway designed to operate only during exceptionally large floods. Generally has a vegetated earth surface.

Energy dissipater – Part of a structure placed to reduce kinetic energy of fast flowing water.

Flood plain – For dams, the downstream area that would be affected by failure of the dam.

Flood storage – Temporary detention of runoff water.

Front slope – The upstream face of a dam.

Groin – General area of contact between the abutment and embankment slopes.

Hazard classification – A rating given to a dam that indicates probable loss of life and property damage downstream should the dam suddenly fail. Value of the reservoir impounded by a dam is also a consideration.

Impervious/Impermeable – Condition of rock, sediment, or soil that renders it incapable of, or very resistant to, transmitting fluids under pressure.

Leakage – Undesirable flow of water through joints, cracks and openings in hydraulic structures.

Outlet channel – The open ditch or stream carrying water from a principal spillway.

Phreatic surface – The free surface of water seeping at atmospheric pressure through soil or rock. In earth dams, the top of the saturated zone within the embankment.

Piping – The progressive internal erosion of embankment, foundation or abutment material. Frequently leads to catastrophic failure.

Principal spillway – The main spillway for normal and flood flows which maintains water level of the lake. Constructed of non-erodible materials, this structure may be either (1) a metal or concrete pipe through the dam incorporating an inlet control or (2) a concrete open throat type that may or may not be gated.

Reservoir/Pool – The body of water impounded by a dam.

Riprap – Broken rock, broken concrete or fieldstone placed to provide protection from erosion.

Seepage – Passage of water through the embankment, the foundation or abutment.

Sinkholes – Generally, a cone shaped vertical hole in the embankment indicating that piping (internal erosion) is occurring. They may also occur as the result of overlying material falling into an animal burrow or into a void created by decaying tree roots or a stump.

Spalling - Chipping or flaking of a concrete surface.

A trash rack keeps debris, like the oil tank above, out of the principal spillway inlet structure of a dam.

Spillway – Structure through which flow is safely discharged to protect the integrity of the dam. Flow may have adjustable control or be fixed by design of the inlet so that reservoir stage predetermines discharge.

Stilling basin – A basin constructed to dissipate energy of fast flowing water, as from a spillway. A principal purpose is to protect a spillway outlet channel from erosion.

Toe drain – A seepage interceptor drain located along or beneath the downstream toe of a dam. Generally, a perforated pipe surrounded by pervious material.

Toe of dam – Junction of the face of a dam with the natural ground surface.

Trash rack – A structure of metal or concrete bars located at a spillway inlet to prevent entry of debris into the spillway.

Trench drain – A granular drain set in a vertical position constructed across the downstream foundation. Trench drains typically penetrate the foundation and extend up into the dam embankment. A collector pipe is usually installed near the base of the trench drain.

Watershed – Land area from which water runoff drains by gravity to a point of reference.

Weep holes – Drainage holes at the base of retaining walls or spillway walls for relief of hydrostatic pressure.

Weir – The metal or concrete edge or surface of a drop inlet over which water flows into a spillway. The cross-section of a weir may be sharp, broad or ogee.